# ADULT CHLOROPIDAE (DIPTERA) ASSOCIATED WITH CONSTRUCTED TREATMENT WETLANDS MODIFIED BY THREE VEGETATION MANAGEMENT TECHNIQUES[1]

**J. B. Keiper[2], M. Stanczak[2], and W. E. Walton[3]**

ABSTRACT: Eight genera of Chloropidae were collected from experimental wetland research cells manipulated by different vegetation control strategies in southern California, U.S.A. After flooding, chloropids were collected with detergent pan traps for 14 months. *Eribolus californicus*, a secondary invader of emergent wetland plants, was the only abundant species. Results indicate that density of adult Chloropidae was not affected differently by the wetland plant management techniques used. However, the techniques slowed the growth of emergent macrophytes (particularly bulrush, *Schoenoplectus* spp.) that are the sites of larval development. Therefore, first year data show low numbers of chloropids, with a two- to three-fold increase by year two.

KEY WORDS: Chloropidae, Diptera, adults, wetlands, vegetation management techniques.

Chloropid flies (Diptera: Chloropidae) represent a large family with about 1300 species worldwide (Rogers et al. 1991). Many species of chloropids are considered to be either primary or secondary invaders of plants, especially grasses, sedges, and rushes (Valley et al. 1969, Todd and Foote 1987, Keiper et al. 2002, Beaulieu and Wheeler 2002). Other species appear to exhibit more scavenging habits (Ferrar 1987, Keiper et al. 2002), and yet others are pest species that may be vectors of ocular diseases (*Liohippelates, Siphunculina* spp.) or cause damage to crops (Ferrar 1987). Most species are not anthropophilic.

Wetland environments provide habitat and food for many chloropid species, and their abundance appears to be tied directly to the wetland plant diversity (Valley and Foote 1997). Large numbers of chloropid individuals and numerous species are frequently found in marsh areas (Todd and Foote 1987). However, due to damage caused by human activities, many wetland habitats are threatened, and the restoration or replacement of wetland areas is common practice today (Hammer 1997). Both comparatively old and newly constructed wetland areas are frequently subjected to vegetation management to prevent aquatic plants from eliminating open water areas. Excessive growth of vegetation in constructed wetlands can lead to decreased efficiency in treating wastewater (Marble 1992, Thullen et al. 2002), and provide less suitable habitat for waterfowl and other wildlife than a hemi-marsh (i.e. a marsh with approximately 50 percent vegetation cover and 50 percent open water) (Batzer et al. 1999). A recent paper showed that vegetation management reduced adult shore fly (Diptera: Ephydridae) densities, but populations required less than one year to produce

[1] Received on August 2, 2002. Accepted on March 13, 2004.

[2] Department of Invertebrate Zoology, Cleveland Museum of Natural History, 1 Wade Oval Drive, Cleveland, Ohio 44106 U.S.A. E-mail: jkeiper@cmnh.org.

[3] Department of Entomology, University of California, Riverside, California 92521 U.S.A.

Mailed on August 25, 2004

equally dense communities during experimental vegetation management in southern California (Keiper and Walton 2002). This study describes the colonization of chloropid flies associated with experimental constructed treatment wetlands subjected to three different vegetation management strategies. It also tests the null hypothesis that densities of abundant species are not significantly affected by these methods of wetland management in southern California, U.S.A.

## MATERIALS AND METHODS

The study was conducted at the Hemet/San Jacinto Regional Water Reclamation Facility in western Riverside County, CA (USA) (Keiper and Walton 2002). Eight 0.1 ha research cells (69 x 14m) were used and divided into three categories after all cells were burned and dried to leave only underground rhizomes. Three cells were randomly assigned as control cells (C). Three remaining cells were randomly selected and scoured with a rock bucket attached to a backhoe (S). The remaining two cells had hummocks (earthen mounds) installed in the shallow areas after the cells were scoured (H). Hummocks were designed to provide shallow areas to focus emergent vegetation, primarily California bulrush (*Schoenoplectus californicus* [Meyer] Sojak), while keeping areas between hummocks free of vegetative growth. Each cell received secondary-treated wastewater containing excess nitrogen (~9.9 mg $L^{-1}$ $NH^{+}_{4}$-N, and <1 mg $L^{-1}$ $NO^{-}_{3}$-N) from the treatment plant. Other workers studying the research cell complex concurrently found that H cells reduced ammonium levels by 66 percent and 28 percent during 1998 and 1999, respectively. Vegetative cover was reduced by approximately 40 percent in the H cells (Thullen et al. 2002).

Flooding of the cells began July 13, 1998, and was completed after 7 days. On the second day of this flooding, detergent pan traps (23 x 33 cm) were set out along the western edge of each of the cells; one on either end, and one in the middle, to represent a variety of open water, plant, and mud shore microhabitats. Pans were set out every week for the first 12 weeks of inundation, every 2 to 3 weeks in the summer of 1999, and less frequently during early spring and winter. Trapping was concluded on September 10, 1999. Each pan was filled with approximately 5 cm of water, to which a few drops of liquid dishwashing detergent were added; insects alighting on the surface fell through the surface and drowned (Larson and Foote 1997, Keiper and Walton 2002). Pans and their contents were collected after 24 hours and preserved for later analysis. Keiper and Walton (2002) provide a more detailed description of the study site and the methods used. Representative specimens were dehydrated and pinned, and are deposited in the Entomology Research Museum of the University of California – Riverside, or the Department of Invertebrate Zoology, Cleveland Museum of Natural History.

Species were categorized as abundant (>20 percent of all specimens captured), common (>10 but <20 percent), uncommon (>1 but <10 percent), or rare (<1 percent). Statistical analyses were applied only to species that were abundant. Nonparametric (Friedman's repeated measures ANOVA) or parametric (one-way repeated measures ANOVA) statistics were performed where appropriate to test the hypothesis that the numbers of adults captured differed significantly between the wetland treatments (SigmaStat 1997). Due to the time of initial inundation and dates sampled during each year, the two years were treated separately.

## RESULTS

A total of 452 chloropids from eight genera were collected. *Eribolus californicus* was the only abundant species and was first encountered 10 days after flooding began. *Pseudopachychaeta approximatonervis* (Zetterstedt) was common but was not captured until approximately 4 months after flooding of the cells. *Elachiptera nigriceps* Loew Sabrosky arrived quickly (24 days after flooding), but was uncommon. The remaining five genera each accounted for <1 precent of the total number of chloropid flies collected (Table 1).

*Eribolus californicus* was infrequently collected during the first summer and fall of the study, with mean densities never exceeding two individuals per pan trap in all treatments. However, by early spring of 1999, densities increased two- to threefold and peaked in June at approximately six individuals per trap. Numbers declined during summer (Fig. 1). However, the abundance of adult *E. californicus* during 1998 ($\chi^2 = 0.273$, d.f. = 2, p = 0.88) and 1999 ($F_{2,7} = 1.03$, p = 0.38) did not differ significantly among the three treatment types.

## DISCUSSION

Previous work on shore flies showed that populations of some common taxa were inhibited by the scoured and hummock treatments during the first summer of inundation. However, all treatments produced statistically equal numbers of individuals by the second year (Keiper and Walton 2002). *Eribolus californicus* was the only abundant chloropid species, and adult density was statistically equal in all treatments. The addition of hummocks to cells reduced the vegetation coverage by 40 percent, and was the most successful management technique in terms of reducing lateral growth of bulrush (Thullen et al. 2002). Although we conducted no rearing, California bulrush grew in a virtual monoculture in the cells and is probably the larval food source for *E. californicus*. Other *Eribolus* species exhibit secondary herbivory in the larval stage (Valley and Foote 1997). The relative scarcity of *E. californicus* during 1998 was probably due to a lack of substantive stands of bulrush in the cells, although a modest peak in numbers occurred in November as bulrush stands were maturing. Peaks in 1999 occurred in April and June. Sampling did not continue until November 1999, thus we can not conclude with certainty that November is a period when a late generation of *E. californicus* occurs. From these data, we suggest that in southwestern habitats, *E. californicus* is at least bivoltine with generations in April and June, and is possibly trivoltine with a peak in November. *Eribolus* species are most commonly found in May and early June in more temperate areas but can be found from mid-April to late October (Valley and Foote 1997).

Table 1. Chloropidae taken in pan traps at the Hemet/San Jacinto RWRF Research Cell Complex, 1998-1999; taxa arranged phylogenetically. Abundance in parentheses: A = abundant (>20%), C = common (>10 but <20%), U = uncommon (>1 but <10%), R = rare (<1%).

| Taxa | Trophic level | Frequency | Days until first appearance |
|---|---|---|---|
| *Pseudopachychaeta approximatonervis* | Herbivore | 0.15 (C) | 122 |
| *Biorbitella* sp. | ? | <0.01 (R) | 24 |
| *Eribolis californicus* | Herbivore/ $2^0$ invader | 0.77 (A) | 10 |
| *Elachiptera nigriceps* | Herbivore/ $2^0$ invader | 0.06 (U) | 24 |
| *Liohippelates* sp. | Herbivore | <0.01 (R) | 248 |
| *Gaurax* sp. | Scavenger | <0.01 (R) | 65 |
| *Rhopalopterum* sp. | Herbivore/ $2^0$ invader | <0.01 (R) | 79 |
| *Apotropina* sp. | Scavenger | <0.01 (R) | 72 |

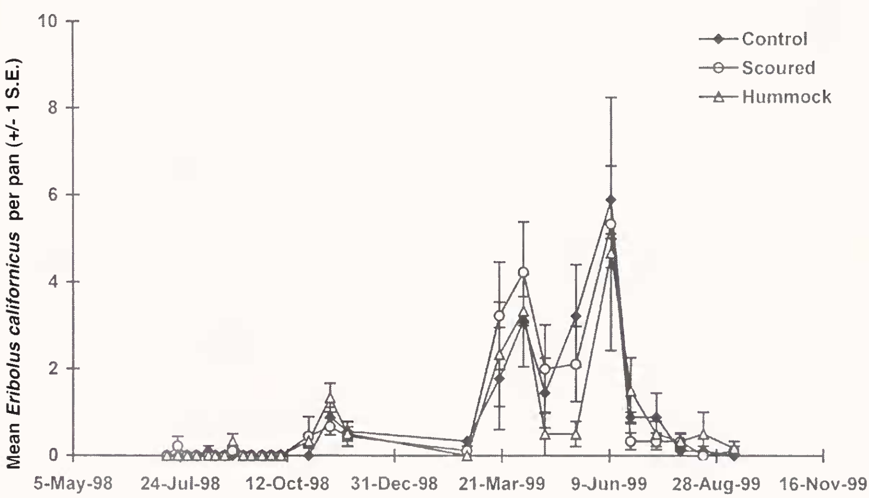


Fig. 1. Mean number of *Eribolus californicus* taken in pan traps from research cells modified by three different vegetation management strategies.

The second most frequently encountered chloropid was *Pseudopachychaeta approximatonervis,* a herbivore which feeds on the inflorescences of plants such as spike-rush (Todd and Foote 1987). Due to repeated captures in a bulrush monoculture, *P. approximatonervis* may be using *S. californicus* as a host plant. The late appearance of *P. approximatonervis* (124 days, Table 1) may have been due to the time it takes for *S. californicus* to flower and eventually develop seed heads. *Elachiptera nigriceps* (Loew) is a secondary invader that normally feeds on shoots of *Carex* and partially opened flowers of *Iris*; the primary invaders of these plants are larvae of Lepidoptera. *Elachiptera nigriceps* is also known to scavenge decaying skunk cabbage (Ferrar 1987) and may opportunistically scavenge decaying plant matter in the areas where skunk cabbage occurs.

The remaining five genera were rare. Flies of the genus *Apotropina* are scavengers as larvae, and are found in the nests of birds or wasps (Ferrar 1987); tricolor blackbirds and marsh wrens, among other avian taxa, nested in the research cells (JBK, personal observation). Some larvae of *Gaurax* can be found feeding on the decaying plant material in bird nests, while others are found in bracket fungi associated with Coleoptera larvae. It has been suggested that *Gaurax* larvae also feed on beetle frass (Valley et al. 1969), while some species are known to be predators of spider egg cocoons (Ferrar 1987). The genus Liohippelates was a rare genus in this study, and contains flies known as eye gnats, which may be vectors of ocular disorders and yaws—skin ulcers on face, feet, and hands (Rogers et al. 1991). Some have been found on the yellow water lily (Todd and Foote 1987), but no evidence suggests that they are associated with bulrush. *Rhopalopterum* is a genus of secondary invaders that inhabit stems of wetland monocots (Keiper et al. 2002). Some plants attacked by this genus are grasses, sedges, and cattails (Todd and Foote 1987). No information on the biology or feeding habits of the genus *Biorbitella* is known.

In conclusion, the chloropid community in these wetland cells is relatively rich with eight species, with certain species (*Eribolis californicus, Pseudopachychaeta approximatonervis,* and *Elachiptera nigriceps)* occurring frequently. Vegetation management practices did not appear to inhibit species richness within the research cells. However, when compared to what little work has been done in natural wetlands, the constructed wetlands harbored far fewer species of Chloropidae (e.g. Todd and Foote 1987). Perhaps if more than one plant species was seeded, the research cells would support a more species-rich community of chloropid flies. The adult flies may be an important food source for birds and amphibians, and the larvae could represent significant herbivores or scavengers, therefore contributing substantially to energy flow and nutrient cycling within constructed wetland ecosystems.

## ACKNOWLEDGMENTS

We thank J. Thullen (USGS), J. Sartoris (USGS), and J. Somsuvanskul (Eastern Municipal Water District) for support and cooperation during this study. M. Sanford, K. Chan, L. H. Gould, J. Jiannino, L. Randall, and P. D. Workman (UCR) helped with field and laboratory work. M. Sanford, D. Dunn (CMNH), as well as an anonymous reviewer, kindly reviewed the manuscript. The study was supported, in part, by Special Funds for Mosquito Research from the Division of Agriculture and Natural Resources of the University of California, USDA funding to the Agricultural Experiment Station at UCR, and the California Mosquito and Vector Control Association Research Foundation.

## LITERATURE CITED

**Batzer, D. P., R. B. Rader, and S. A. Wissinger.** 1999. Invertebrates in Freshwater Wetlands of North America: Ecology and Management. Wiley, New York. 1120 pp.

**Beaulieu, F. and T. A. Wheeler.** 2002. Insects (Diptera, Coleoptera, Lepidoptera) reared from wetland monocots (Cyperaceae, Poaceae, Typhaceae) in southern Quebec. Proceedings of the Entomological Society of Washington 104:300-308.

**Ferrar, P.** 1987. A guide to the breeding habits and immature stages of Diptera, Cyclorrhapha. Entomonograph Volume 8. Scandinavian Science Press Ltd. 448 pp.

**Hammer, D. A.** 1997. Creating Freshwater Wetlands. CRC Press, Inc., Boca Raton. 240 pp.

**Keiper, J. B. and W. E. Walton.** 2002. Effects of three vegetation management strategies on shore-flies (Diptera: Ephydridae) in newly constructed treatment wetlands. Annals of the Entomological Society of America 95:570-576.

**Keiper, J. B., W. E. Walton, and B. A. Foote.** 2002. Biology and ecology of higher Diptera from freshwater wetlands. Annual Review of Entomology 47:207-232.

**Larson, L. and B. A. Foote.** 1997. Biology of four species of *Notiphila* Fallén (Diptera: Ephydridae) associated with the yellow water lily, *Nuphar luteum* (Nymphaeaceae). Proceedings of the Entomological Society of Washington 99:542-59.

**Marble, A. D.** 1992. A Guide to Wetland Functional Design. Lewis Publishers, Boca Raton. 240 pp.

**Rogers, T. P., B. A. Foote, and J. L. Todd.** 1991. Biology and immature stages of *Chlorops certimus* and *Epichlorops exilis* (Diptera: Chloropidae), stem borers of wetland sedges. Journal of the New York Entomological Society 99:664-683.

**SigmaStat.** 1997. SigmaStat statistical software. SPSS Inc., Chicago. 250 pp.

**Thullen, J. S., J. J. Sartoris, and W. E. Walton.** 2002. Effects of vegetation management in constructed wetland treatment cells on water quality and mosquito production. Ecological Engineering 18:441-457.

**Todd, J. L. and B. A. Foote.** 1987. Resource partitioning in Chloropidae (Diptera) of a freshwater marsh. Proceedings of the Entomological Society of America 89:803-810.

**Valley, K. V. and B. A. Foote.** 1997. Biology and immature stages of *Eribolus longulus*, with notes on *E. nanus* (Diptera: Chloropidae), secondary invaders of herbaceous wetland plants. Memoirs of the Entomological Society of Washington 18: 273-279.

**Valley, K. V., R. T. Wearsch, and B. A. Foote.** 1969. Larval feeding habits of certain Chloropidae. Proceedings of the Entomological Society of Washington 71: 29-34.